Understanding Particle Pollution

Particle Pollution Is...

Complex

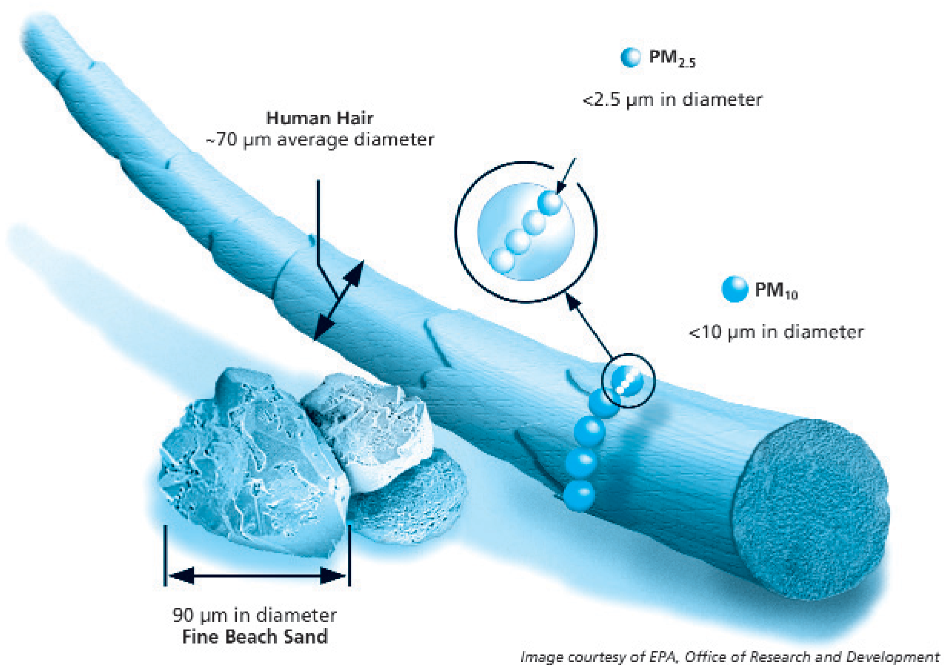
Perhaps no other pollutant is as complex as particle pollution. Also called particulate matter or PM, particle pollution is a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small, they can only be detected using an electron microscope.

These tiny particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some particles are emitted directly from a source, while others form in complicated chemical reactions in the atmosphere. And some can change back and forth from gas to particle form. Particle pollution also varies by time of year and by location and is affected by several aspects of weather, such as temperature, humidity, and wind.

A Continuum of Sizes

In general, particle pollution consists of a mixture of larger materials, called "coarse particles," and smaller particles, called "fine particles." Coarse particles have diameters ranging from about 2.5 micrometers (µm) to more than 40 µm, while fine particles, also known as known as $PM_{2.5}$, include particles with diameters equal to or smaller than 2.5 µm. EPA also monitors and regulates PM_{10}, which refers to particles less than or equal to 10 µm in diameter. PM_{10} includes coarse particles that are "inhalable" — particles ranging in size from 2.5 to 10 µm that can penetrate the upper regions of the body's respiratory defense mechanisms. "Ultrafine" particles are a subset of $PM_{2.5}$, measuring less than 0.1 µm in diameter.

Figure 1. Comparison of PM sizes.

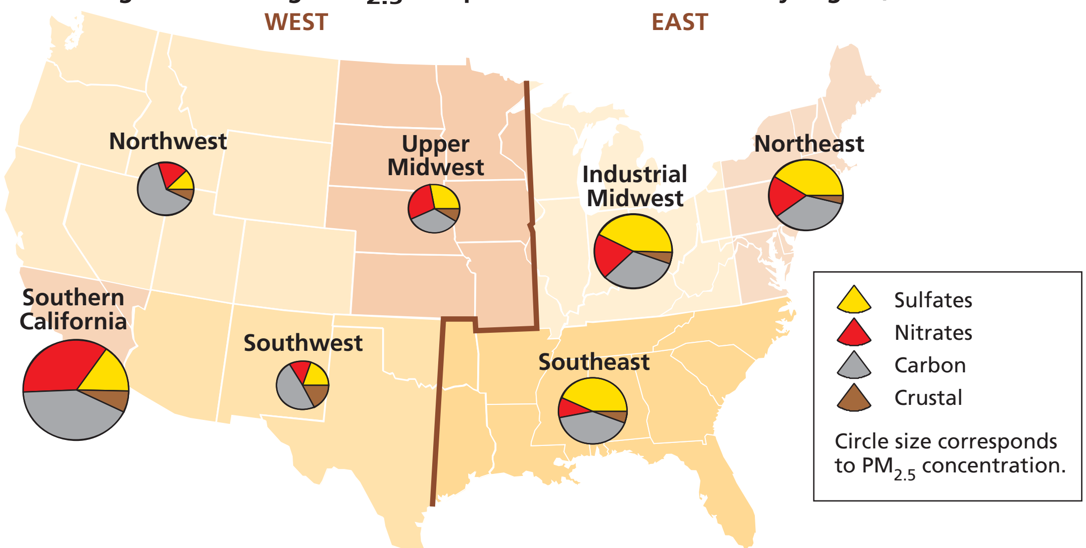


Note: In this report, particle size or diameter refers to a normalized measure called aerodynamic diameter, which accounts for the irregular shape and varying density of most particles.

Made Up of Many Species

Particles are made up of different chemical components. The major components, or species, are carbon, sulfate and nitrate compounds, and crustal materials such as soil and ash. The different components that make up particle pollution come from specific sources and are often formed in the atmosphere (see "Sources and Transport of Particle Pollution" on page 6). The chemical makeup of particles varies across the United States (see Figure 2). For example, fine particles in the eastern half of the United States contain more sulfates than those in the West, while fine particles in southern California contain more nitrates than other areas of the country. Carbon is a substantial component of fine particles everywhere. (For information on the composition of ultrafine and coarse particles in Los Angeles, see page 7.)

Figure 2. Average $PM_{2.5}$ composition in urban areas by region, 2003.



Note: In this report, the term "sulfates" refers to ammonium sulfate and "nitrates" refers to ammonium nitrate. "Carbon" refers to total carbonaceous mass, which is the sum of estimated organic carbon mass and elemental carbon. "Crustal" is estimated using the IMPROVE equation for fine soil at vista.cira.colostate.edu/improve.

This report summarizes analysis results using the geographic areas shown in this map. The area definitions correspond to the regions used in EPA's 1996 PM Criteria Document (www.epa.gov/ttn/naaqs).

In this report, "East" includes three regions: the Northeast, the Industrial Midwest, and the Southeast.

Health and Environmental Effects of Particulate Matter

Health Effects

Exposure to particles can lead to a variety of serious health effects. The largest particles do not get very far into the lungs, so they tend to cause fewer harmful health effects. Coarse and fine particles pose the greatest problems because they can get deep into the lungs, and some may even get into the bloodstream. Scientific studies show links between these small particles and numerous adverse health effects. Long-term exposures to PM, such as those experienced by people living for many years in areas with high particle levels, are associated with problems such as decreased lung function, development of chronic bronchitis, and premature death. Short-term exposures to particle pollution (hours or days) are associated with a range of effects, including decreased lung function, increased respiratory symptoms, cardiac arrythmias (heartbeat irregularities), heart attacks, hospital admissions or emergency room visits for heart or lung disease, and premature death. Sensitive groups at greatest risk include people with heart or lung disease, older adults, and children.

Environmental Effects

Fine particles are the major source of haze that reduces visibility in many parts of the United States, including our national parks. PM affects vegetation and ecosystems by settling on soil and water, upsetting delicate nutrient and chemical balances. PM also causes soiling and erosion damage to structures, including culturally important objects such as monuments and statues.

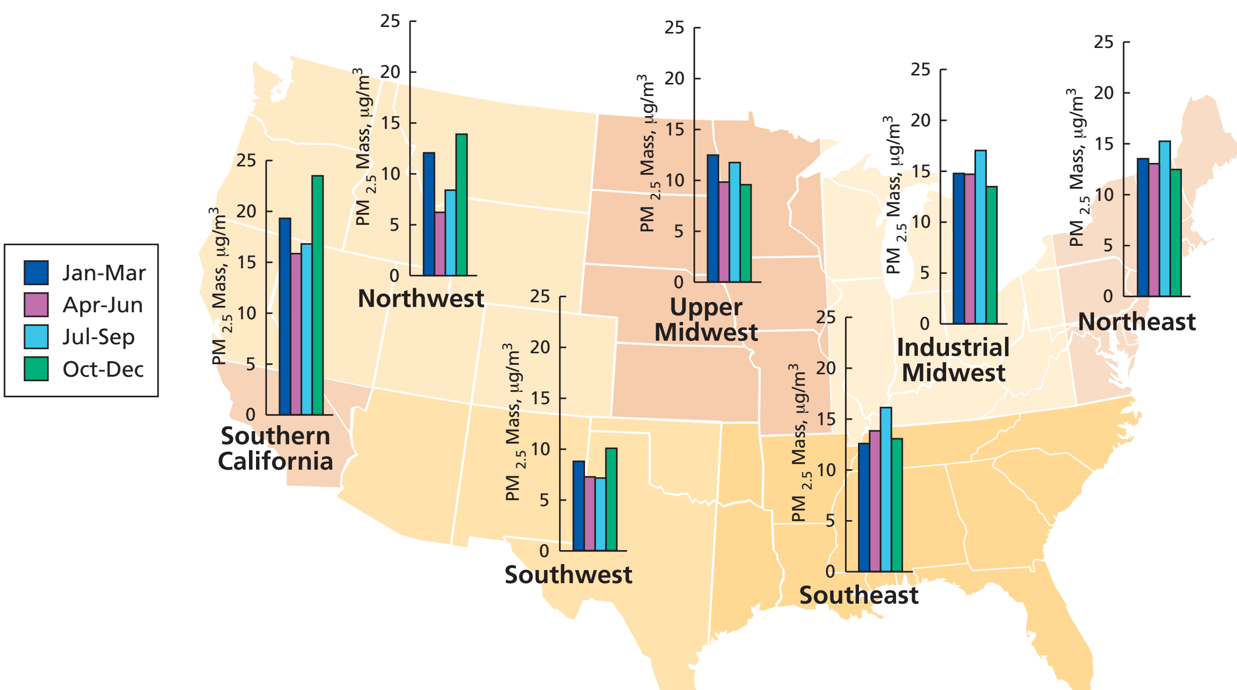
Particle Pollution Is...

Seasonal

Fine particles often have a seasonal pattern. $PM_{2.5}$ values in the eastern half of the United States are typically higher in the third calendar quarter (July-September) when sulfates are more readily formed from sulfur dioxide (SO_2) emissions from power plants in that region. Fine particle concentrations tend to be higher in the fourth calendar quarter in many areas of the West, in part because fine particle nitrates are more readily formed in cooler weather, and wood stove and fireplace use produces more carbon.

The time of year also influences *daily* fine particle patterns. Unlike daily ozone levels, which are usually elevated in the summer, daily $PM_{2.5}$ values at some locations can be high at any time of the year. Figure 4 shows 2003 $PM_{2.5}$ levels for Fresno and Baltimore. The colors in the background of these charts correspond to the colors of the Air Quality Index (AQI), EPA's tool for informing the public about air pollution levels in their communities. As the Fresno graphic illustrates, fine particles can be elevated in the fall and winter in some areas, while ozone is elevated only in the summer. Contrast the Fresno graphic with the Baltimore graphic, which shows PM elevated year-round. Note: Elevated levels on the AQI do not indicate that an area is violating EPA's national air quality standards for any particular pollutant. The AQI is designed to help people reduce their individual exposure to pollution.

Figure 3. Seasonal averages of $PM_{2.5}$ concentration by region, 1999–2003.

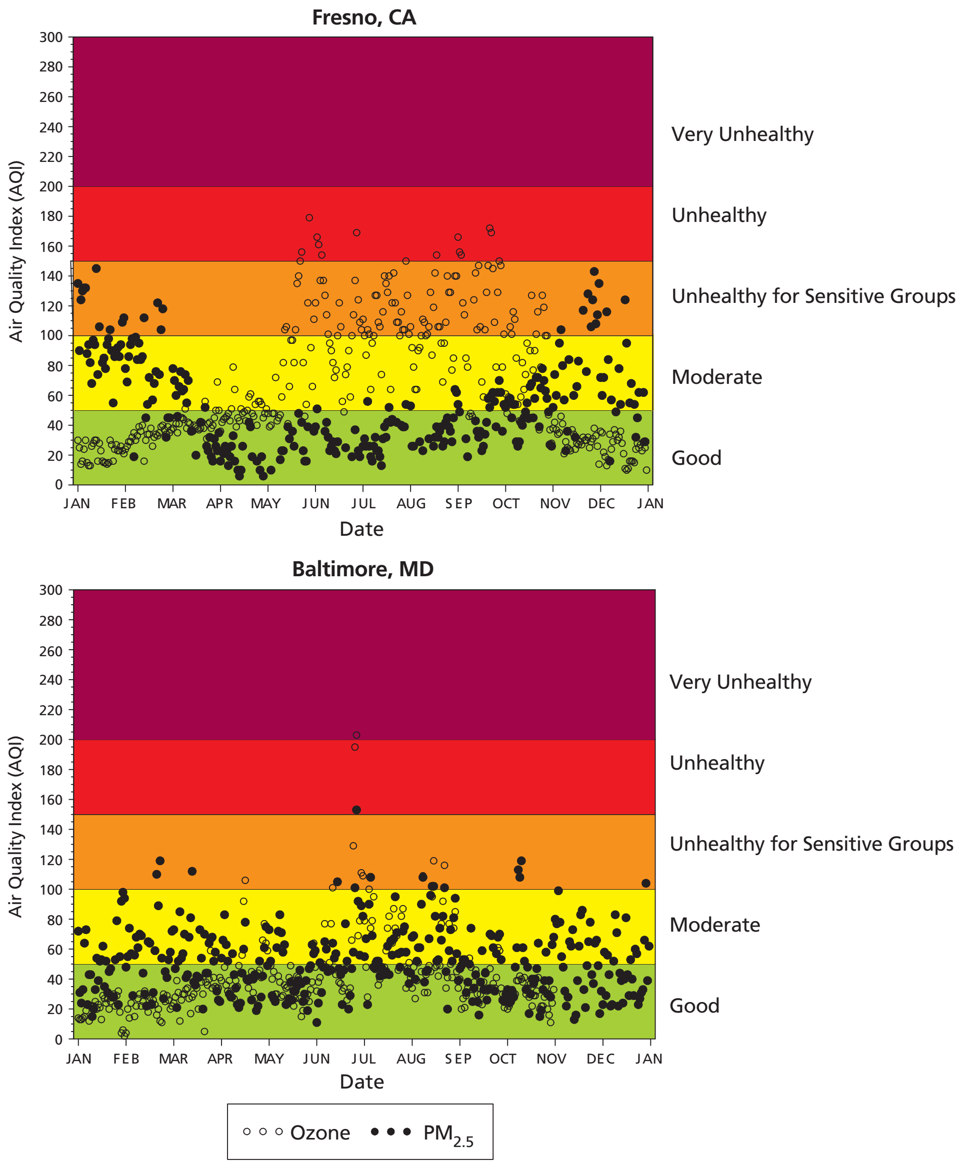


Air Quality Index (AQI) - Particulate Matter

The AQI is an index for reporting daily air quality. It tells how clean or polluted the air is and what associated health effects might be a concern. The AQI focuses on health effects people may experience within a few hours or days after breathing polluted air. EPA calculates the AQI for five major pollutants regulated by the Clean Air Act: particulate matter, ozone, carbon monoxide, sulfur dioxide, and nitrogen dioxide. The AQI values for particulate matter are shown here.

AQI	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	Air Quality Descriptor
0–50	0.0–15.4	0–54	Good
51–100	15.5–40.4	55–154	Moderate
101–150	40.5–65.4	155–254	Unhealthy for Sensitive Groups
151–200	65.5–150.4	255–354	Unhealthy
201–300	150.5–250.4	355–424	Very unhealthy

Figure 4. Daily $PM_{2.5}$ and ozone AQI values, 2003.



Note: These graphs represent data from Federal Reference Method monitors. They do not show data from all monitors that report the Air Quality Index.

Sources and Transport of Particle Pollution

Sources

Particulate matter includes both "primary" PM, which is directly emitted into the air, and "secondary" PM, which forms indirectly from fuel combustion and other sources. Generally, coarse PM is made up of primary particles, while fine PM is dominated by secondary particles.

Primary PM consists of carbon (soot) — emitted from cars, trucks, heavy equipment, forest fires, and burning waste — and crustal material from unpaved roads, stone crushing, construction sites, and metallurgical operations.

Secondary PM forms in the atmosphere from gases. Some of these reactions require sunlight and/or water vapor. Secondary PM includes

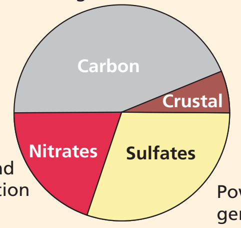
- *Sulfates* formed from sulfur dioxide emissions from power plants and industrial facilities
- *Nitrates* formed from nitrogen oxide emissions from cars, trucks, and power plants
- *Carbon* formed from reactive organic gas emissions from cars, trucks, industrial facilities, forest fires, and biogenic sources such as trees.

Note: For more information about the apportionment of fine particles to their sources, go to www.epa.gov/oar/oaqps/pm25/docs.html

Transport

In the atmosphere, coarse and fine particles behave in different ways. Larger coarse particles may settle out from the air more rapidly than fine particles and usually will be found relatively close to their emission sources. Fine particles, however, can be transported long distances by wind and weather and can be found in the air thousands of miles from where they were formed.

Automobiles, Power Generation, and Other Sources Contribute to Fine Particle Levels



Note: Ammonia from sources such as fertilizer and animal feed operations contributes to the formation of sulfates and nitrates that exist in the atmosphere as ammonium sulfate and ammonium nitrate.

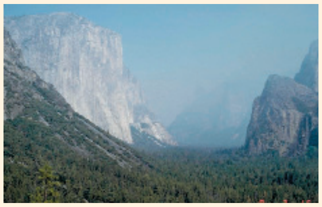
Visibility

One of the most obvious effects of air pollution occurs both in urban areas and at the country's best-known and most-treasured national parks and wilderness areas. Visibility impairment occurs when fine particles scatter and absorb light, creating a haze that limits the distance we can see and that degrades the color, clarity, and contrast of the view. The particles that cause haze are the same particles that contribute to serious health problems and environmental damage.

Visibility impairment—and the concentration of particles that cause it—generally is worse in the eastern United States than it is in the West. Humidity can significantly increase visibility impairment by causing some particles to become more efficient at scattering light. Average relative humidity levels are higher in the East (70% to 80%) than in the West (50% to 60%).

In the East, reduced visibility is mainly attributable to sulfates, organic carbon, and nitrates. Poor summertime visibility is primarily the result of high sulfate concentrations, combined with high humidity. Sulfates, which dominate the composition of these visibility-impairing particles, have been found to contribute even more to light extinction than they do to fine particle concentrations. In the West, organic carbon, nitrates, and crustal material make up a larger portion of total particle concentrations than they do in the East.

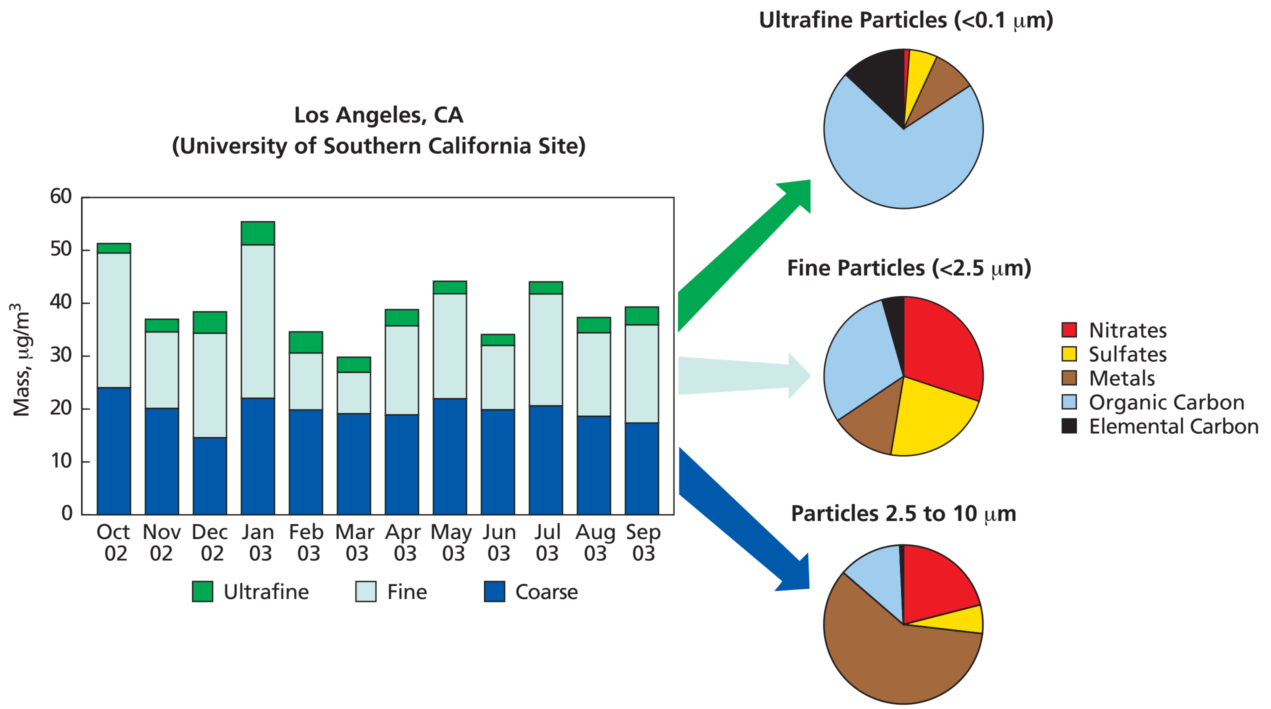
Through its 1999 regional haze rule, EPA, states, and other federal agencies are working to improve visibility in 156 national parks and wilderness areas such as the Grand Canyon, Yosemite, the Great Smokies, and Shenandoah. Five multistate regional planning organizations are working together to develop and implement regional haze reduction plans. For more information, see www.epa.gov/airtrends/vis.html.




Yosemite National Park (California) under bad and good visibility conditions. Visual range is 111 kilometers (km) in the left photo and greater than 208 km in the right photo.


Shenandoah National Park (Virginia) under bad and good visibility conditions. Visual range is 25 km in the left photo and 180 km in the right photo.

PM Supersites



Note: "Crustal materials" include windblown soil, industrial process emissions, sea salt, and flyash from combustion.

After issuing the nation's first $PM_{2.5}$ standards in 1997, EPA developed the PM Supersites project, a monitoring research program, to address a number of scientific issues associated with particulate matter. Program goals focus on obtaining atmospheric measurements to

- Characterize PM, its constituents, atmospheric transport, and source categories that affect PM in any region
- Compare and evaluate different PM measurement methods (e.g., emerging sampling methods, routine monitoring techniques)
- Support exposure and health effects research concerning the relationships between sources, ambient PM concentrations, and human exposures and health effects and the biological basis for these relationships.

EPA selected eight locations for Supersites, including Los Angeles. Atmospheric measurements taken at the Los Angeles site between October 2002 and September 2003 show that ultrafine particles make up a small portion of the PM concentration compared to inhalable coarse and fine particles. However, the *number* of ultrafine particles is significantly larger than the number of coarse or fine particles. EPA is studying this from a health perspective.

The Los Angeles data also show that coarse, fine, and ultrafine PM have different compositions. For each type of PM, there is a difference in the relative amounts of nitrates, sulfates, crustal materials, and carbon. Carbon, shown here as organic and elemental carbon, makes up a large fraction of ultrafine and fine PM in Los Angeles.

For more information, see www.epa.gov/ttn/amtic/supersites.html and www.epa.gov/ttn/amtic/laprog.html

Both Local and Regional

Both local and regional sources contribute to particle pollution. Figure 5 shows how much of the $PM_{2.5}$ mass can be attributed to local versus regional sources for 13 selected urban areas (arranged west to east). In each of these urban areas, monitoring sites were paired with nearby rural sites. When the average rural concentration is subtracted from the measured urban concentration, the estimated local and regional contributions become apparent.

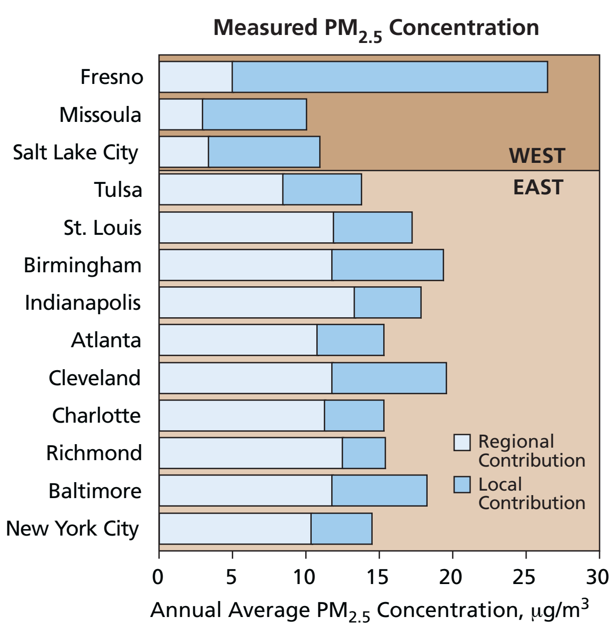
In the East, regional pollution contributes more than half of total $PM_{2.5}$ concentrations. Rural background $PM_{2.5}$ concentrations are high in the East and are somewhat uniform over large geographic areas. These regional concentrations come from emission sources such as power plants, natural sources, and urban pollution and can be transported hundreds of miles.

For the cities shown in Figure 5, local contributions range from 2 to 20 micrograms per cubic meter (µg/m³), with the West generally showing larger local contributions than the East. In the East, local contributions are generally greatest in cities with the highest annual average $PM_{2.5}$ concentrations.

Figure 6 shows the local and regional contributions for the major chemical components that make up urban $PM_{2.5}$: sulfates, carbon, and nitrates. In the eastern United States, the local contribution of sulfates is generally small. Most sulfates in the East are converted from regional SO_2 emissions and are transported long distances from their sources.

Carbon has the largest local contribution of the three major chemical components. These local emissions come from a combination of mobile and stationary combustion sources. The regional

Figure 5. Local and regional contribution to urban $PM_{2.5}$.

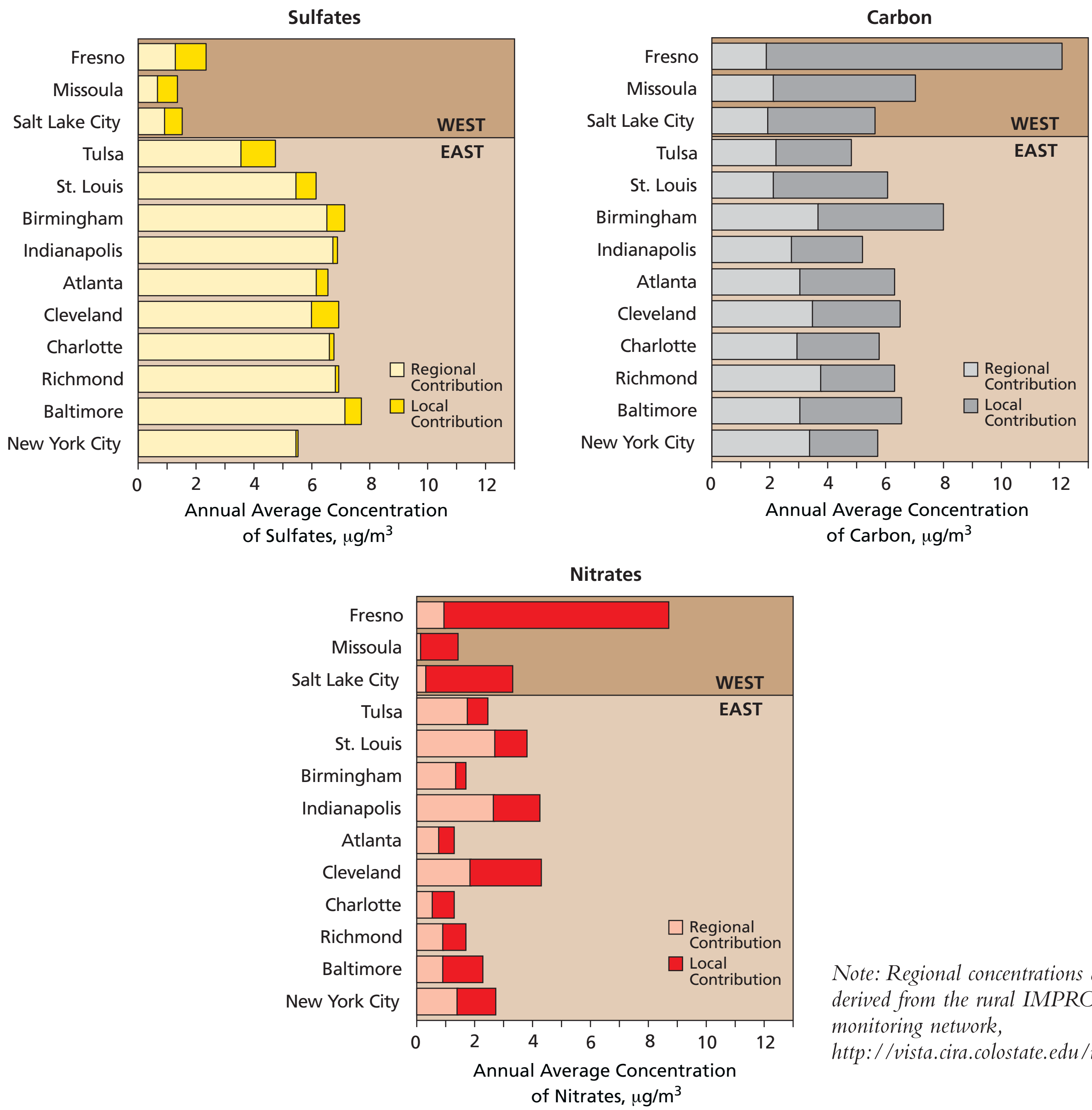


Note: Urban and nearby rural $PM_{2.5}$ concentrations suggest substantial regional contributions to fine particles in the East. The measured $PM_{2.5}$ concentration is not necessarily the maximum for each urban area. Regional concentrations are derived from the rural IMPROVE monitoring network, http://vista.cira.colostate.edu/improve.

contribution, which varies from 30% to 60% of the total carbon at urban locations, is from rural emission sources such as vegetation and wildfires, as well as region-wide sources such as cars and trucks.

Nitrates represent only about 10% to 30% of annual average $PM_{2.5}$, and urban concentrations are higher than the nearby regional levels. This is likely due to local nitrogen sources such as cars, trucks, and small stationary combustion sources.

Figure 6. Local and regional contribution of major $PM_{2.5}$ chemical components.



Note: Regional concentrations are derived from the rural IMPROVE monitoring network, http://vista.cira.colostate.edu/improve.